STATE OF WASHINGTON
Albert D. Rosellini, Governor

DEPARTMENT OF CONSERVATION
Earl Coe, Director

DIVISION OF WATER RESOURCES
Murray G. Walker, Supervisor

Water Supply Bulletin No. 8

Geology and Ground Water Resources of the Columbia Basin Project Area, Washington

Volume I

By

Kenneth L. Walters and Maurice J. Grolier

Prepared in Cooperation with
UNITED STATES GEOLOGICAL SURVEY
GROUND WATER BRANCH
1960

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Price $1.50, Division of Water Resources, Olympia, Wn.

FOREWORD

Volume I of the "Geology and Ground Water Resources of the Columbia Basin Project Area, Washington" represents the first phase of a program designed to (a) determine the availability and suitability of ground water for municipal supply, farm use and industry within the Columbia Basin Project, (b) delineate areas that might eventually become waterlogged as a result of irrigation, (c) interpret chemical quality and chemical changes of ground water, if any, and (d) evaluate the possibility of pumping ground water for irrigation and/or drainage purposes.

Volume I contains factual data for hundreds of wells drilled within the project boundary and a brief summary of water level changes that have occurred as a result of project irrigation.

Volume II, scheduled for release in 1961, will contain a discussion of the occurrence and movement of ground water; the geology of the Columbia Basin project, with special emphasis on the stratigraphy of the Columbia River basalt, and a thorough analysis of the effects of project irrigation on the regional water table.

The program was started in 1939 as a cooperative effort between the Washington State Division of Water Resources and the U. S. Geological Survey. The program was interrupted during World War II but was re-activated in 1948.

Volume I is not designed to delineate problem areas or recommend a remedial program, but is presented with the thought that it will serve as a valuable reference for farmers, irrigation districts and other agencies actively engaged with the problems associated with the rising water table.

Everything possible has been done to insure the completeness and accuracy of the data presented herein. It is my privilege to submit herewith Volume I of "Geology and Grand Water Resources of the Columbia Basin Project Area, Washington".

-Robert H. Russell
Assistant Supervisor
Division of Water Resources

CONTENTS

	Page
Extent and description of area	1
Scope and purpose of report	2
Previous investigations	4
Well-numbering system	6
Acknowledgments	6
Geologic setting	7
Rock units and their water-bearing characteristics	7
Columbia River basalt	7
Ringold formation	9
Palouse formation	9
Glacial outwash sand and gravel	10
Dune sand	10
Effects of irrigation upon water levels	11
Winchester-Burke area	12
Moses Lake area	16
Warden area	17
Othello area	18
Minor areas of shallow ground water	19
Explanation of data	21
Location of wells	21
Configuration of the water table	22
Configuration of the Columbia River basalt surface	22
Well records	22
Hydrographs	24

		Page
Explanation of data--Continued		
	Logs of wells--	25
	Chemical analyses of water from wells------------------	25
List of references--		26

ILLUSTRATIONS

Plate 1.	Well-location map----------------------------------	In back
2.	Water-table map------------------------------------	In back
3.	Basalt-surface map---------------------------------	In back
Figure A.	Map showing location of areas in which water levels generally were within 30 feet of land surface in 1958------------------------------------	13
1-24	Hydrographs of selected wells----------------------	519

TABLES

Table 1.	Records of wells------------------------------------	28
2.	Chemical analyses of water from wells---------------	338
2A.	Partial chemical analyses of water from wells--------	348
3.	Logs of wells--	351

GEOLOGY AND GROUND WATER RESOURCES OF

THE COLUMBIA BASIN PROJECT AREA, WASHINGTON

VOL. I

By

Kenneth L. Walters and Maurice J. Grolier

EXTENT AND DESCRIPTION OF AREA

The investigation in which the data presented here were collected covers an area of about 3,900 square miles of the semiarid plateau of central Washington, including parts of Grant, Franklin, and Adams Counties. The area includes lands being developed or considered for development under the Bureau of Reclamation's Columbia Basin Irrigation Project, plus an additional 200 square miles northwest of Ephrata which is hydrologically related to, but not a part of, the reclamation project. The area lies north and east of the Columbia River in the reach from Trinidad to the confluence with the Snake River near Pasco. The area extends eastward to approximately the line between Ranges 32 and 33 E. and northward to an irregular boundary passing through Trinidad, Soap Lake, and Wilson Creek.

The area consists of a number of small structural basins and ridges, and it takes on the aspect of a single major basin only when the major structural ridges lying beyond the west and south boundaries of the area are considered. The most prominent topographic feature in the area is the structural ridge known as Saddle Mountains, which rises about 2,000 feet above the adjacent flood plain of Crab Creek. A lower ridge, the Frenchman Hills, lies about 12 miles north of and parallel to the Saddle Mountains. The altitude of the land surface ranges from more than 2,700 feet in the Saddle Mountains to less than 350 feet near Pasco.

The surface of the area is broken by several major coulees and scabland tracts which represent former glacial drainageways. Only two perennial streams, Rocky Ford and Crab Creeks, now traverse the area; most of the former channels or drainageways are either dry or carry intermittent flow.

Tracts of fixed and semifixed sand dunes occur at several places. Migration of one of these tracts of dunes across the channel of Crab Creek impounded the flow of that creek to form Moses Lake, the largest natural lake in the area.

Precipitation in the area ranges from about 8 inches in the western part to about 10 inches in the east. Locally, this precipitation is great enough to support dry farming of wheat, although generally throughout the area it is adequate only for such native vegetation as sagebrush, bunchgrass, and associatea desert flora.

SCOPE AND PURPOSE OF REPORT

The Geological Survey currently is making two ground-water investigations in the general area encompassed by the Columbia Basin Irrigation Project. One, in cooperation with the U. S. Bureau of Reclamation, involves the collection and compilation of basic data for use by that agency in project operation and drainage planning. The other, in cooperation with the Washington State Department of Conservation, Division of Water Resources, involves evaluation of ground-water resources in parts of Grant, Adams, and Franklin Counties and correlation of ground-water occurrence with geologic environment.

This report is intended to serve a twofold purpose. It will supply to the U. S. Bureau of Reclamation, in one volume, data that hitherto have been furnished that agency informally as the data were collected. The data supplied to the U. S. Bureau of Reclamation are applied to the solution of many problems that are inherent in any undertaking of the magnitude of the Columbia Basin Irrigation Project. The use of surface water for irrigation has resulted in a rising water level locally and also in local ponding. The efficient resolution of problems such as these is an integral part of the work of that agency. The report also will supply information to the Washington State Department of Conservation as a basis for answering the many queries concerning the availability of ground water in the areas under investigation. As a result of the greater emphasis on an agricultural economy for these areas, public interest in ground water for domestic and stock use also will increase, and queries regarding the availability of ground water will, of course, increase also.

The project being undertaken in cooperation with the U. S. Bureau of Reclamation is a continuing one, in which hydrologic data will be supplied to that agency as long as the need for the data continues. The Project in cooperation with the State Department of Conservation will lead to a comprehensive report relating the occurrence of ground water more closely to geologic conditions. By delineating the stratigraphic and structural relationships of the basalt sequence, the most important ground-water reservoir, or aquifer, in the area, the report will show which zones in the basalt are water bearing and which are barren to have poor yield. With this knowledge, a more accurate prediction of well yield, ground-water movement, and water-level fluctuation can be made.

Ground-water projects of the U. S. Geological Survey in the State of Washington are under the immediate supervision of A. A. Garrett, District Engineer. Prior to 1957 such projects were under the supervision of M. J. Mundorff, former District Geologist. Large blocks of data appearing in this report were collected over a period of many years by previous investigators. In addition to the data collected and compiled by the authors of the report and those collected by authors of reports listed on page 26, significant amounts of field work were done by B. L. Foxworthy, G. D. Holmberg, and R. L. Washburn of the U. S. Geological Survey.

The Division of Water Resources of the Washington State Department of Conservation is under the leadership of M. G. Walker, Supervisor, and R. H. Russell, Assistant Supervisor.

Liaison with the U. S. Bureau of Reclamation has been chiefly through E. H. Neal, Irrigation Supervisor, and Edwin Nasburg, Chief, Hydrography and Drainage Branch, Columbia Basin Irrigation Project.

PREVIOUS INVESTIGATIONS

The first investigation of the ground-water resources of parts of the area was undertaken by Russell in 1897. Other investigations were made by Smith (1901), Landes (1905), Calkins (1905), Waring (1913), Schwennesen and Meinzer (1918), and Jenkins (1922).[1]

In 1940 the U. S. Geological Survey, in cooperation with the State of Washington Department of Conservation, Division of Water Resources, began a ground-water investigation in the Columbia Basin Project area. Data obtained during the period August 1940 through

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[1] See page 26 for list of references cited.

1942 were compiled and assembled by Taylor (1944). Taylor (1948) described the ground-water conditions based on these data and on a field study of the geology.

For planning purposes in regard to the irrigation project, more detailed information was needed, chiefly with reference to the availability of ground water for domestic and municipal supply. For this reason, and because of the large number of wells drilled since completion of the previous well inventory in 1942, the study was reactivated in July 1949, financed jointly by the Geological Survey, the State of Washington, and the Bureau of Reclamation.

As a part of this investigation, all known wells in the area were canvassed, well logs were collected from drillers, water samples were collected for chemical analysis, geologic cross sections were constructed on the basis of well logs, and limited geologic mapping and water-level measurementsin wells of the observation network established in 1940 were continued. The study resulted in a report titled "Progress Report on Ground Water in the Columbia Basin Project, Washington," by Mundorff, Reis, and Strand (1952).

Since 1953 the investigation has consisted almost entirely of the gathering of additional basic ground-water and geologic data, under similar joint financing. Records and logs of many new wells have been collected as they were drilled, and recurrent water-level records have been maintained to determine changes in ground-water levels as irrigation development progressed. Data on yield and drawdown of wells have been collected wherever available. About 85 observation wells were measured monthly or bimonthly, and on several of them semicontinuous water-stage recorders were maintained.

WELL-NUMBERING SYSTEM

Well numbers used by the Geological Survey in the State of Washington are based on and show locations of wells according to the rectangular system for subdivision of public land, indicating township, range, section, and 40-acre tract within the section. For example, in the well number 20/25-14N1, the part preceding the hyphen indicates successively the township and range (T. 20 N., R. 25 E.) north and east of the Willamette base line and meridian. The first number after the hyphen indicates the section (sec. 14) and the letter (N) gives the 40-acre subdivision of the section as shown in the diagram. The last number (1) is the serial number of the well in that particular 40-acre tract.

Thus, the first well recorded in the $SW\frac{1}{4}SW\frac{1}{4}$ sec. 14, T. 20 N., R. 25 E., would have the number 20/25-14N1, and the second well would have the number 20/25-14N2.

D	C	B	A
E	F	G	H
M	L	K	J
N	P	Q	R

14N1

ACKNOWLEDGMENTS

The field work for this report was facilitated by the helpful cooperation of the many well owners, tenants, and well drillers who supplied information and allowed access to the wells. Personnel of the Department of Conservation and Bureau of Reclamation have been very helpful in supplying maps, well logs, and other valuable information. The assistance of all is gratefully acknowledged.

GEOLOGIC SETTING

The area covered in this report is a part of the extensive Columbia River plateau, which was formed by the extrusion of lava during the Eocene, Miocene, and Pliocene(?) epochs throughout a large part of eastern Washington, eastern Oregon, and western Idaho.

After basalt was extruded, the region was warped into the form of a broad basin, in which several subbasins were formed by locally steeper folding and by faulting. In these subbasins deposits of clay, silt, sand, and gravel accumulated during the Pleistocene, or glacial, epoch.

Also during Pleistocene time, and continuing into Recent time, the area has recieved deposits of silt and sand carried by the wind. These eolian deposits in part are being reworked and shifted by the winds at the present time.

The basalt bedrock and coarse-grained sedimentary deposits in the subbasins constitute the important sources of ground water in the area. The basalt ridges that separate the subbasins also are important to the occurrence of ground water in that they may act as ground-water barriers, retarding the movement of ground water from one subbasin to the other.

ROCK UNITS AND THEIR WATER-BEARING CHARACTERISTICS

Columbia River Basalt

The Columbia River basalt underlies all the area of this study. Older granitic and metamorphic rocks underlying the basalt are exposed in areas bordering the Columbia Basin Project area, and are thought to underlie the basalt under all or much of the area. Nowhere in the area is the total thickness of the basalt known. About 1,800 feet of basalt is exposed where the Columbia River has eroded a gorge through Saddle Mountains near Beverly, and an oil test hole (well 17/28-19D1) penetrated basalt to a depth of 4,470 feet without reaching the base of the formation. Locally, at least, the Columbia River basalt probably exceeds 10,000 feet in thickness.

The Columbia River basalt is composed of a series of lava flows ranging in thickness from a few feet to more than 100 feet. The lava probably was extruded from numerous fissure-type openings rather than from a relatively small number of craters. The dominant material of the individual flows is dense dark generally fine-grained basalt which often displays prominent vertical jointing. The upper portions of many of the flows are porous and vesicular, having a scoriaceous crust indicative of rapid cooling and movement of the fluid inner portion of the flow after the surface had solidified. Locally pillow lavas occur where flows were extruded into water or upon a damp surface.

At places, individual flows are separated by sedimentary "interbeds" consisting of tuffaceous material, volcanic ash, sand, and clay. The thickness of the interbeds ranges from a few inches to several tens of feet.

The term Columbia River basalt is used in this report to designate all basalt in the area. Thus it includes not only the sequence of flows that is essentially unbroken by sedimentary interbeds, but also includes the upper basalt units that are intercalated with layers of sedimentary materials. In their discussions of the geology of the project area Taylor (1948) and Mundorff and others (1952), used the name Yakima basalt; however, that name is now considered to be a somewhat more restrictive designation than the Columbia River basalt, and should be applied only in those areas where the basalt sequence definitely can be correlated with the type area in Yakima County. Inasmuch as such correlation has not been accomplished throughout the project area, the more general name Columbia River basalt is here applied.

The permeable zones in the upper portions of some of the flows yield large quantities of water to wells. The dense middle and lower parts of the flows and the occasional sedimentary interbeds usually yield little, if any, water to wells.

Ringold Formation

In much of the area the Columbia River basalt is overlain by sedimentary deposits of Pleistocene age, designated the Ringold formation. These deposits, which occur chiefly in the structural basins, range in thickness from a few feet to more than 600 feet.

The Ringold formation consists primarily of fine sand, silt, and clay. Locally, however, it contains a layer of conglomerate, composed of well-rounded pebbles and cobbles in a matrix of clay and siliceous sand as much as 165 feet thick. Newcomb (1958) considers this conglomerate to be a river-deposited gravel train.

In general, the Ringold formation yields only meager supplies of water, and most of the wells that encounter the Ringold are extended into the underlying Columbia River basalt.

Palouse Formation

Much of the Columbia Basin Project area is mantled by loess, which tentatively is assigned to the Palouse formation, of Pleistocene age (Bryan, 1927). This massive, structureless silt is believed to be wind-deposited material derived largely from the older Ringold formation. The thickness of the Palouse formation ranges from a few feet in the western part of the area, where only isolated patches remain, to more than 100 feet in the eastern part of the area. The Palouse formation is above the water table nearly everywhere in the area; locally, however, where saturated, it yields small amounts of water to wells.

Glacial Outwash Sand and Gravel

Deposits of predominately basaltic sand and gravel, deposited in part by glacial meltwater, are widely distributed throughout the area. These deposits occur as extensive sheets, terrace deposits, and channel fillings, and locally they attain thicknesses in excess of 100 feet. Where their saturated thickness is considerable, as in the Quincy and Soap Lake areas, glacial outwash deposits yield large quantities of water, and much irrigation water was obtained from wells tapping those materials before the Bureau of Reclamation irrigation project was begun.

Dune Sand

There are two large tracts of sand dunes in the area. One of these is just southwest of Moses Lake and the other is immediately northeast of Pasco. Most of the dunes are fixed or semifixed, but at places the dunes upon which no vegetative cover has been established are gradually migrating to the east or northeast, in the direction of prevailing winds.

The Dunes are composed of well-sorted fine to very fine-grained sand, probably derived largely from materials in adjacent or underlying bodies of Ringold formation, but possibly also from sands of the outwash materials.

The dune tract located northeast of Pasco lies above the water table and is therefore unsaturated. The dune sands in the area southwest of Moses Lake are partially saturated and may be capable of yielding sizable quantities of ground water to wells, although to date no attempt has been made to exploit this potential aquifer.

EFFECTS OF IRRIGATION UPON WATER LEVELS

In the Columbia Basin Irrigation Project area application of surface water to large acreages of land started in 1952 when about 21,800 acres were brought under irrigation. In 1953 about 36,800 acres, in 1954 about 40,500 acres, in 1955 about 44,900 acres, in 1956 about 26,900 acres, in 1957 about 26,900 acres and in 1958 about 35,200 acres were irrigated for the first time. The canals serving each of the acreages cited above carried water on a pre-test basis late in the summer of the year preceding the first year of irrigation. In 1948, 232 acres were irrigated by water pumped from the Columbia River near Pasco and in 1950 irrigation with water pumped from the Snake River near Pasco was started. In 1951, about 5,300 acres were irrigated with water pumped from the Columbia and Snake Rivers near Pasco. Pumpage from the Columbia River near Pasco was discontinued in 1954, and the land that had formerly been irrigated by water from that source is now irrigated by water pumped from the Columbia River at Grand Coulee Dam. Additional acreages in the Pasco area were brought under irrigation in 1958 with water pumped from the Snake River.

An intensive program of water-level measurements in the project area was carried out during April to July 1958 to determine the effects of irrigation upon water levels to that date. A comparison of water levels in wells before irrigation was started with levels in the same wells in 1958, after several years of irrigation, reveals that in some a marked rise in level has occurred. The areas in which water levels in wells generally were within 30 feet or less of the surface as of 1958 are shown in figure A. Although a water-level depth of 30 feet below land surface does not necessarily represent an undesirable condition, this depth was arbitrarily chosen as representing shallow water-table conditions for the purpose of this discussion. In much of the project area where water levels in most wells are within 30 feet of the surface at least locally, there is enough relief that springs or seeps are likely to develop in low places. That is to say, in each of these areas water levels range in depth from 0 to about 30 feet below land surface. In the Columbia Basin Irrigation Project, there are four major areas of tillable land in which water levels have risen to within 30 feet or less of the surface since the onset of irrigation. They are shown on figure A and are discussed below. These four are not all the areas shown on figure A in which water levels in wells are within 30 feet or less of the surface; the other areas, however, because they are either principally of nontillable soils, of naturally shallow water levels bordering bodies of surface water, or with insufficient data on changes of water level in wells to determine whether there have been any effects of application of irrigation water, are not considered to be of major importance and are discussed in less detail.

Winchester-Burke Area

The Winchester-Burke area was brought under surface water irrigation during the years 1952 to 1955. In this area water levels rose abruptly in 1952, after a period of at least several years during

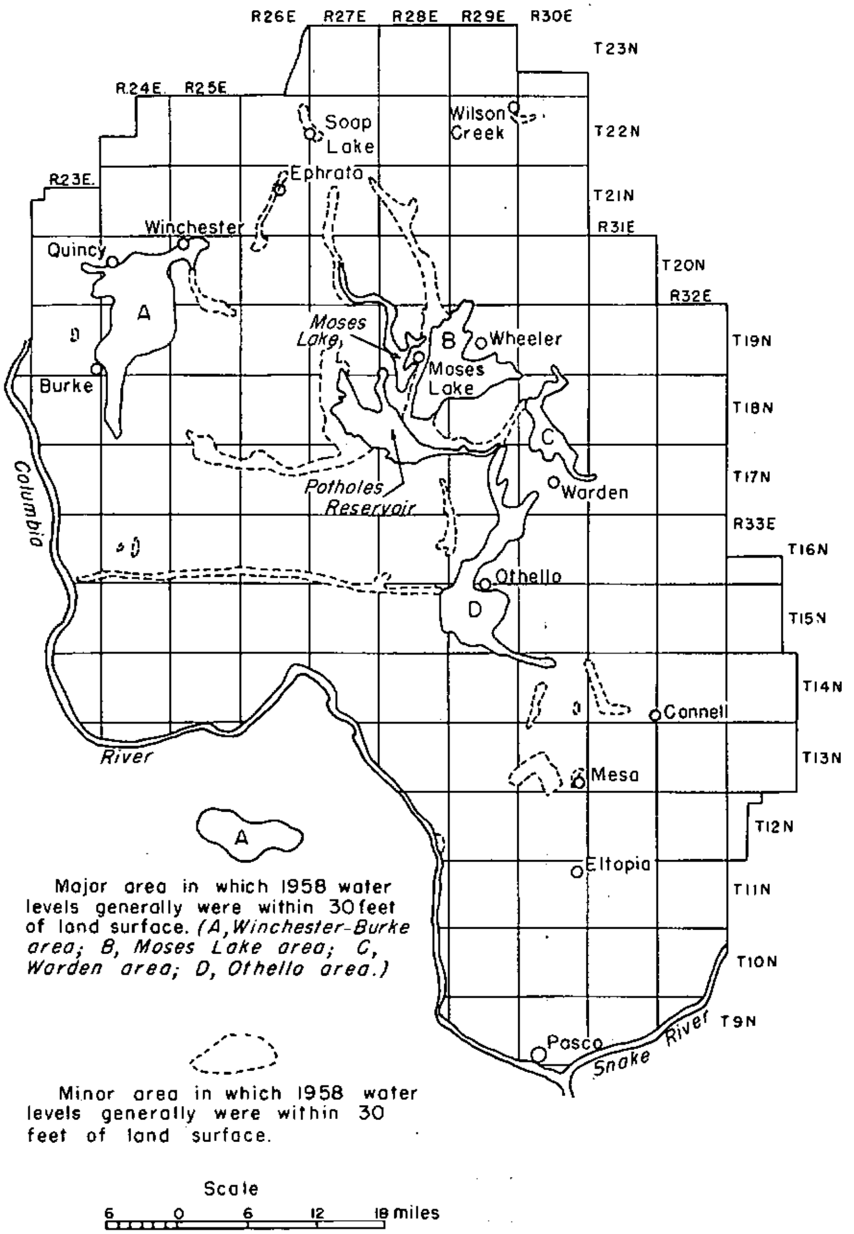

Figure A -- Map showing location of areas in which water levels generally were within 30 feet of land surface in 1958.

which they had remained fairly constant. This rise in water level is clearly illustrated by the hydrograph for well 20/25-7L1 shown on figure 15. Of the 60 wells in the Winchester-Burke area in which water-level measurements have been taken since the early 1950's, all show to some degree a consistent rise in level to 1958. Preirrigation water levels in this area ranged from about 125 feet to more than 300 feet below land surface. In 1958 water levels in a majority of the wells measured were less than 30 feet below land surface.

Of the 60 wells, the changes in water levels over different periods of records for each well varied from a decline of 2 feet in well 20/24-33B1 to a rise of about 295 feet in well 20/23-25E1, representing an average net rise of about 70 feet for each well. This indicated average rise doubtless is considerably less than the true average rise for the whole period beginning with the start of irrigation. The foregoing data would more closely represent the actual field conditions if records for all wells had included the first years of irrigation--many of the 60 wells were measured only during the period 1956-1958, a period during which water levels in many wells became more stable. The average yearly rise in water level in the 60 wells for different segments of the interval 1952 to 1958 was about 17 feet per year. Of the 60 wells, the average yearly rise in water level in 8 for which measurements are available from 1952 to 1956 was about 28 feet whereas the average yearly rise in 41, measured from 1956 to 1958, was only about 5 feet. For the whole period 1952 to 1958 the average yearly rise in water level in 15 wells was about 26 feet.

In 1958 the average depth to water in this area, based on measurements in 59 wells, was about 23 feet below land surface. Water-level measurements have been continued in only 4 wells beyond the date of collection of the data upon which the above statements are based. Of these, well 20/25-7L1 began flowing late in 1958, the other 3 wells, 18/24-6H1, 19/24-2D1 and 19/24-24M1, have averaged about 1 foot of rise per month since mid-1958. Some ponding of water on the land surface has occurred, indicating that locally--in low places--the water table is at land surface.

In the Winchester-Burke area the basalt bedrock is overlain, for the most part by semi-consolidated fine sand, silt, and clay. These semi-consolidated deposits are overlain by varying thicknesses of unconsolidated sand and gravel. In general, the unconsolidated and semi-consolidated deposits were above the water table before irrigation started, and also during the first few years of irrigation when the rise in water levels occurred only in the basalt bedrock. As the level rose above the top of the basalt, the overlying unconsolidated deposits became saturated. The decreased rate of rise as water levels became within a few tens of feet below land surface probably is due in part to the greater porosity of the unconsolidated deposits than that of the basalt as a whole, and in part to the work of drains and wasteways east of this area--both the land surface and the buried basalt surface slope rather gently east or southeast, toward the lowest part of a depression or basin in Rs. 25 and 26 E. where a wasteway has been constructed.

Similar rises in water level in wells have occurred in a band which more or less encircles the area previously discussed and which ranges in width from about half a mile to more than 2 miles. This area is different from the main area discussed, only in that the preirrigation water levels were somewhat deeper and the 1958 water levels in a majority of the wells were somewhat greater than 30 feet below land surface.

Moses Lake Area

Most of the area immediately east and southeast of the city of Moses Lake was brought under irrigation with surface water in 1952 and 1953. Based on water-level measurements in 14 wells, preirrigation water levels in this area ranged about from 30 to 235 feet below land surface and averaged about 110 feet below land surface. Hydrographs for several wells in the area, 18/28-2L1, 19/28-25L1, and 19/29-34D1, shown respectively on figures 7, 12, and 11, indicate an abrupt rise in water level in 1952 or 1953. In 1958 the average depth to water in 22 wells was about 25 feet below land surface and in the 28 wells for which records are available changes in water levels since 1952 ranged from a rise of more than 200 feet to a decline of more than 5 feet. The average total rise in water levels in the 28 wells was about 50 feet per well; however, as was the case in the area discussed earlier, not all the records cover the same time intervals for all wells. The average yearly rise in water level in the 28 wells for different segments of the interval 1952 to 1958 was about 12 feet. Of the 28 wells, the average yearly rise in water level in 6 for which measurements were available from 1952 to 1956 was about 23 feet. The average yearly rise in water level in 11 wells measured from 1952 to 1958 was about 14 feet. The average yearly rise in 11 wells measured from 1954 through 1958 was less than 1 foot per year.

Water-level measurements in only 4 wells have been continued beyond the date of collection of the data upon which the above statements are based. Levels in these wells have shown only normal seasonal fluctuations, and if they indicate conditions for the entire area it can be assumed that water levels in the area have changed but very little since 1958.

In this area the basalt bedrock is overlain be clay, caliche, sand, and gravel averaging about 40 feet in thickness. The decreased rate of rise in water level since about 1955 may be due in a small part to greater porosity of the material near the surface, but is more likely due to increased westward migration of ground water toward Moses Lake and the Potholes Reservoir.

Along the southeast margin of the area just described, is an area ranging in width from about half a mile to more than 3 miles in which the average depth to water in 1958 was about 65 feet. Although some pronounced rises in water levels have occurred in this marginal area since 1952, the problem of shallow water levels may not develop in most of this area because of fairly well established subsurface drainage into Lind Coulee and Weber Coulee.

Warden Area

The Warden area was brought under irrigation with surface water in 1954 and 1955. The hydrograph for well 18/30-34M1 (fig. 1) shows a rise in water level of about 20 feet in 1954, although for 11 years preceding 1954 the level fluctuated but very little. Although water-level data are available for only a few wells in this area, these data, even though fragmentary, suggest strongly that changes in water levels since irrigation began are similar in magnitude to those in the Moses Lake area. Before irrigation began in this area water levels ranged from less than 50 to about 150 feet in depth below land surface, and averaged about 80 feet below land surface. In 1958 the average depth to water was about 30 feet below land surface, representing an average yearly rise of about 10 feet. Although sufficient data are not available to determine accurately the water-level trend in the most recent years of irrigation, the hydrograph of well 18/30-34M1 indicates that the water level in that well has not yet stabilized. The highest observed water level in this well in 1959 was about 5 feet higher than in 1958, or about 48 feet below land surface.

In the Warden area the basalt bedrock is overlain by about 30 to 100 feet of unconsolidated deposits. The bedrock surface is a wide trough occupied by Lind Coulee and Weber Coulee; here, practically all lateral migration of ground water is probably to the west.

Othello Area

Irrigation of parts of the Othello Area with surface water was started in 1953, and although available data on deep wells are not sufficient to determine accurately the effects of irrigation on wells tapping basalt, measurements of water levels in a number of shallow wells indicate that in general, water levels in 1958 were less than 30 feet below land surface.

Records are available for 14 wells installed by the Bureau of Reclamation in this area from 1952 to 1955. These wells, called drainage observation wells by the Bureau of Reclamation, are all 50 feet deep and none encountered water when drilled. In 1958, however, water levels in these wells ranged in depth from 10 feet to 43 feet below land surface and averaged about 20 feet below land surface. Of the 14 wells, only one encountered basalt. It penetrated only 10 feet of weathered basalt mixed with clay and caliche. Water levels in several deeper wells in the area that tap basalt were more than 100 feet below land surface in 1958. It is believed, therefore, that the shallow water levels in much of this area represent the surface of a perched or semi-perched ground water body underlain by the more impervious silt and clay overlying the basalt.

Southwest of Othello the basalt surface is in the form of a basin or depression. A body of water, known locally as Lake Linda, has formed in this depression since the advent of irrigation. The area of this lake was about 80 acres in 1954, and swampy conditions have developed for a considerable distance northwest and southeast of Lake Linda.

An area of several square miles in the southeast corner of T. 15 N., R. 29 E. and in the south west corner of T. 15 N., R. 30 E. is geologically similar to the area just discussed; water levels here have risen considerably since irrigation began. For example, well 15/29-26A2 (a 50-foot drainage observation well) was dry when drilled in 1954; in 1959 the water level in this well was about 28 feet below land surface. This area has better subsurface drainage than most of the areas discussed above and water levels probably will not continue to rise as rapidly as they have in the past.

Minor Areas of Shallow Ground Water

Numerous areas in which the water table was near the surface in 1958 are shown in figure A but are not discussed in detail. Some of these areas are small and their presence is indicated by observations of water levels in only one or two wells. For example, in the area a few miles west of Mesa and in the area a few miles west of Connell a rise in water level in the past several years has been detected but evidence of that rise is based on data from only 2 or 3 wells in each area. Other areas of shallow water levels occur adjacent to natural or artificial bodies of surface water, and fluctuations of water level in these areas are in response to changes in levels of these surface water bodies. Examples of such areas are the long narrow area bordering Crab Creek east of Beverly, areas bordering Moses Lake and the streams tributary to it, an area around Soap Lake, and a small area near Wilson Creek. Although these are natural areas of shallow ground water, their size has, in nearly every case, been increased materially since the advent of irrigation. Examples of areas of shallow ground water bordering artificial bodies of surface water are those near the Potholes Reservoir, and along wasteways west of the Potholes Reservoir and southeast of Winchester.

Ponding of water on the land surface has occurred locally in some areas. Most cases of ponding have occurred in poorly drained nontillable areas such as that in the sand dune tracts west and northwest of the Potholes Reservoir, and in the basalt scabland south of the Potholes Reservoir. However, a small area of ponding has developed on tillable land in Esquatzel Coulee near Mesa subsequent to the termination of collection of the data given in this report. The water that is ponded here probably is, for the most part, ground water that has migrated laterally from the irrigated upland area to the northwest. The hydrograph of well 13/30-26G2 (fig. 5), a well which is now almost entirely surrounded by ponded water, shows a rising water level trend starting in 1954 after a period of 13 years during which the hydrograph shows only seasonal water-level fluctuations. Plate 2 shows that in 1958 water levels in the area about 2 miles west of Mesa were about 25 feet higher than the floor of Esquatzel Coulee at Mesa and the direction of ground-water movement in at least part of the area was toward the coulee. The surface of the coulee floor near Mesa is underlain by as much as 65 feet of silt and silty clay. The impervious nature of this material, in conjunction with the poorly developed surface drainage of the coulee in this area, doubtless has also played an important part in causing the ponding mentioned above.

Outbreaks of springs along the valley wall of the Columbia River near Ringold (sec. 24, T. 12 N., R. 28 E.) in October 1957 have resulted in damage to a small acreage of low-lying land near the river in that area. The discharge of these springs--several thousand gallons per minute in the aggregate--is somewhat seasonal, the greatest rate of discharge is from May to October. In May 1958, a second group of springs broke out in a small coulee tributary to the Columbia River about one half mile southeast of the springs mentioned above. The flow of these springs also is seasonal. The greatest flow occurs during the irrigation season and almost no flow occurs during late winter and spring.

EXPLANATION OF DATA

Data that have been collected in the Columbia Basin Project Area are presented chiefly in tabular form on the pages that follow. These data were collected not only during this investigation, but also during earlier investigations already cited.

Location of Wells

The location of all wells and test holes for which data are available is shown on plate 1. The type of data available is shown by means of symbols. Only the portion of the well number that indicates the 40-acre tract and the serial number of the well within that particular 40-acre tract is shown on plate 1.

Configuration of the Water Table

The general configuration of the water table in the area is shown in plate 2. The information shown on this plate is based largely on water-level measurements made by personnel of the Geological Survey during April to July 1958, in wells tapping basalt or deep gravel aquifers. Some reported water levels, as well as water levels measured at earlier dates, were considered in areas where wells are few. Measurements believed to reflect levels in perched or semiperched water bodies were disregarded. Differences in artesian pressures between shallow and deep basalt aquifers may account for some other locally anomalous water-level measurements. Such local anomalies probably do not materially affect the general configuration of the water table as shown.

Configuration of the Columbia River Basalt Surface

The general configuration of the surface of the Columbia River basalt, and the areas in which basalt is exposed, are shown in plate 3. Contours are based on elevations obtained from all available logs of wells in the project area that encounter basalt, and on Geological Survey topographic maps in areas where basalt is exposed at the surface.

Well Records

Table 1 includes records of all wells for which data are available. Headnotes at the beginning of the table explain the different types of information tabulated and the abbreviations used.

All water levels and dates of measurements are given for wells in which four measurements or less have been made. For wells in which more than four measurements have been made, only selected measurements are shown. Recurrent water-level measurements, not here presented, for numerous observation wells in the area are on file at the office of the Geological Survey, Ground Water Branch, Tacoma, Wash.

Water levels in wells were measured by the wetted-tape method or by use of an electrical water-sounding device. In some wells equipped with pressure gages, water levels were determined by the submerged air-line method. For those wells that have no access port for measuring the level, the depth to water and the depth of well are based on drillers' or owners' reports.

Locally, a great number of wells have been drilled to approximately the same depth and penetrate the same sequence of materials; in such areas not all wells have been inventoried. Certain parts of Franklin and Adams Counties are now undergoing rapid development and many wells have been constructed after the field canvass was made; the records of these wells are not included in this data report. Also, unless at least one pertinent feature of a well record, such as depth, depth to water, or material penetrated, could be ascertained the well is not tabulated in this report. Records of well known to have been destroyed are included in table 1 if some pertinent data exist.

Locations of wells were determined by pacing or by odometer measurements from known points; elevations of wells were determined from their plotted locations on U. S. Bureau of Reclamation topographic maps at a scale of 1:12,000 and with 2-foot contour intervals.

Data concerning well yields and water-bearing materials were obtained from well owners and drillers or from the records of the State Department of Conservation or the U. S. Bureau of Reclamation.

Hydrographs

Hydrographs showing water-level fluctuation in selected observation wells are presented in figures 1 to 24. Hydrographs have been prepared only for those wells for which reasonably continuous water-level records, covering periods of at least several years, are available. Water-level records from additional short-term or temporary observation wells are on file at the Ground Water Branch office at Tacoma. The wells for which hydrographs are herein presented, and the number of the figure where each appears, are shown in the following index.

Index of wells for which hydrographs are presented in figures 1 to 24

Well number	Figure	Well number	Figure	Well number	Figure
9/29-25D1	1	19/23-34R1	21	19/31-19B1	5
10/29-19Q1	7	19/24-2D1	6	20/23-10D1	15
11/30-11B1	1	19/24-24M1	16	20/23-12J1	8
13/29-24R1	2	19/25-2N2	13	20/23-28J1	17
13/30-26G2	5	19/25-26N1	14	20/24-1H1	18
14/29-1R1	3	19/25-28M1	5	20/25-7L1	15
15/30-2R1	3	19/26-9C1	5	20/25-15Q1	19
16/25-6M1	10	19/26-20A1	5	20/25-21A2	13
16/29-35R1	9	19/26-34D1	5	20/26-18R1	1
17/24-4J1	4	19/27-16N1	5	20/26-22P1	20
17/27-32H1	4	19/27-26A1	12	20/26-26M1	14
17/28-2G1	3	19/27-28C1	14	20/29-10M1	7
17/28-11F1	4	19/28-6C1	14	20/29-28B1	22
17/29-12C1	3	19/28-8H2	14	20/30-6H1	19
17/31-6P1	3	19/28-10D1	8	21/26-3A2	22
18/24-6H1	11	19/28-15L1	16	21/26-10L2	22
18/24-22D1	3	19/28-20A1	8	21/26-12F1	7
18/25-8M1	7	19/28-25L1	12	21/26-21G1	21
18/25-8N1	7	19/28-34N1	10	21/26-32A1	16
18/28-2L1	7	19/29-6A1	10	21/27-4K1	21
18/29-20B1	2	19/29-14J1	9	21/28-2D1	22
18/30-34M1	1	19/29-34D1	11	21/28-8P1	20

Index of wells for which hydrographs are presented in figures 1 to 24-- Con.

Well number	Figure	Well number	Figure	Well number	Figure
21/28-34A1	1	22/27-23R1	23	22/27-34D1	14
21/30-9P1	1	22/27-29H2	20	22/28-6R1	24
22/27-14M1	23	22/27-29P2	23	22/28-26D1	24
22/27-19N2	20	22/27-30P1	24	22/28-33R1	21
				22/30-18M1	24

Logs of Wells

Table 3 contains information on the character and thickness of material penetrated in all wells in the project area for which such data are available. Logs were collected from well drillers, well owners, and Federal Government agencies during earlier investigations as well as during the current study. No stratigraphic designations have been made. The terminology used is that of the driller or other source; the logs have been edited only to the extent necessary to achieve consistency of presentation.

Chemical Analyses of Water from Wells

Chemical analyses of ground-water samples collected during this and earlier investigations are presented in tables 2 and 2A. Table 2 lists analyses of samples of water from wells for which nearly all the important chemical constituents commonly present in ground water were determined. The principal aquifer supplying the well and the agency or firm which collected and analyzed each sample also is indicated. Table 2A presents field analyses of samples for which tests were made for only selected chemical constituents.

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